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ABSTRACT

A model of attrition for specially admitted black students (low high school achievement and low assessed college aptitude) at the University of Pittsburgh was tested. The majority fell into the lower end of a socioeconomic range and often had inadequate precollege preparation. The attrition model was examined using a linear structural equation technique called LISREL (Joreskog, 1979), which estimates unknown coefficients in a set of equations and specifies hypotheses in terms of cause and effect variables and their indicators. The following variables were assessed: family background, type of high school attended, entry ability, on-campus academic behavior, and attrition. For the 80 black students entering the university in 1976-1977 and 1977-1978 through the special admission program, significant relationships were found among the following variables: entry ability, high school attended, on-campus academic behavior, and attrition. The construct most highly related to attrition was on-campus academic behavior. The important indicators of on-campus academic behavior were the adequate and timely completion of homework, regular class attendance, asking questions in class, careful and complete studying for tests, and putting forth maximum effort for class success. Entry ability was found to be significantly related to the type of high school attended and attrition. Scholastic Aptitude Test (SAT) scores for verbal and math abilities were found to be effective measures of entry ability. Information is provided on: the range of SAT scores of the sample, range of high school ranks, degree expected, family income, parent educational background, and type of high school attended by the study group. Schemata of the model are included. (SW)

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A CAUSAL MODEL OF THE ATTRITION OF SPECIALLY ADMITTED BLACK STUDENTS IN HIGHER EDUCATION

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HE 015 748

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ABSTRACT

This study was designed to develop and test a hypothesized model of the attrition of specially admitted black students at the University of Pittsburgh. LISREL, a linear structural equation technique, was used to test the relationships between latent variables; family background, the type of high school attended, entry ability, on-campus academic behavior, and attrition. Several indicators were used to assess the latent variables, and steps to analyze and modify the fit of the model involved estimating and determining the significance of all unknown parameters, and conducting residual and derivative analyses to determine possible measurement errors and needs for structural modifications. A summary of the findings indicated significant relations among the constructs, entry ability, high school attended, on-campus academic behavior and attrition. Entry ability was found to be significantly related to the type of high school attended and attrition. However, the construct most highly related to attrition was on-campus academic behavior. The important indicators of on-campus academic behavior were the adequate and timely completion of homework, regular class attendance, asking questions in class, careful and complete studying for tests, and putting forth maximum effort for class success.

A Causal Model of the Attrition of Specially Admitted Black Students in Higher Education - Diane D. Eddins

Background

The problem of black students' attrition gave impetus to the establishment of many special programs to admit and support the new student. However, the efforts of these programs to increase student retention were often ineffective. In a study conducted by Sedlacek and Webster (1978), it was reported that although the black freshman enrollment in predominately large universities rose to five percent of entering classes from 1969 to 1976, only about half of these entering freshmen students returned for their sophomore year.

What are the reasons for black student attrition in special opportunity programs? Attempts by schools and programs to mitigate student attrition depends to a great extent on a better understanding of these reasons. Yet, research that has been conducted to identify likely reasons for this attrition has often yielded conflicting and inconclusive findings (Klingelhofer and Hollander, 1973). Past research on the attrition of traditional students has not been without difficulties. Student attrition studies' findings have varied considerably (Pantages and Creedon, 1978). Many of the studies conducted focused on the effects of one or two isolated variables as the primary explanation for student attrition. Most of these investigations failed to recognize the complexity of the attrition process and often assumed that variables relating to student attrition operated independently of each other.

Several researchers have attempted to develop attrition models which would lend conceptual coherence to the myriad of research that has

been conducted in this area (Bean, 1980; Rootman, 1972; Spady, 1971; Tinto, 1975). Generally the reported variables and relationships offered by these models are that student attrition is highly dependent on the adequate fit, congruency, or integration of the individual into the university, and the likelihood of this integration is highly dependent on students' entering characteristics.

Spady (1971) proposed an attrition model which states that students enter college with attributes such as interests, dispositions, expectations and skills, which are shaped mainly by family backgrounds and high school experiences. He further states that it is these backgrounds and experiences that influence the student's interaction with the environmental influences of the university, and provides students with the opportunity for successful assimilation into the social and academic systems of the university.

Tinto (1975) presents an attrition model which appears to have substantial potential for understanding the attrition process of black students. In this model a distinction is made between attrition that is due to voluntary withdrawal and that due to academic dismissal. It is an important distinction to consider when proposing a model on black student attrition, because for black students in higher education, particularly those at large universities, attrition is highly related to academic failure (Kendrick and Thomas, 1970). This is a finding that is contrary to reported findings on the attrition of traditional students, which suggests that most attrition (two-thirds) is attributed to voluntary withdrawal rather than academic failure on the part of the student (Summerskill, 1962). Tinto suggests in his model that overall, voluntary withdrawals and persisting students have similar backgrounds. He further states

however, that: (1) academic dismissal students are from a lower socio-economic status than persisting students; (2) academic dismissal students exhibit lower levels of ability than persisting students; and (3) students who attended private high schools tend to have higher retention rates than those who attended public high schools.

Problem and Design

The purpose of the study was to develop and test a hypothesized model of the attrition of specially admitted black students in higher education. The technique that was used to examine the proposed model was a linear structural equation technique called LISREL (Joreskog, 1979). A structural equation model is one that is used to specify a theory in terms of cause and effect variables and their indicators. LISREL is a technique for estimating the unknown coefficients in a set of linear structural equations. In its general form, the LISREL technique assumes that there is a causal structure among a set of hypothetical constructs which can be designated as either independent or dependent variables. These constructs, referred to as latent variables, are not directly observable but are measured by a set of observed or indicator variables that are related to the latent variables. LISREL is described by Joreskog as a technique designed to handle a wide range of models with latent variables, taking into account measurement errors and reciprocal causation.

The proposed model for this study is presented in Figure 1. It is a causal model which describes the hypothesized relationships among constructs or latent variables. In this model the latent variables are: (1) family background; (2) high school attended; (3) entry ability; (4) on-campus academic behavior; and (5) attrition. These variables

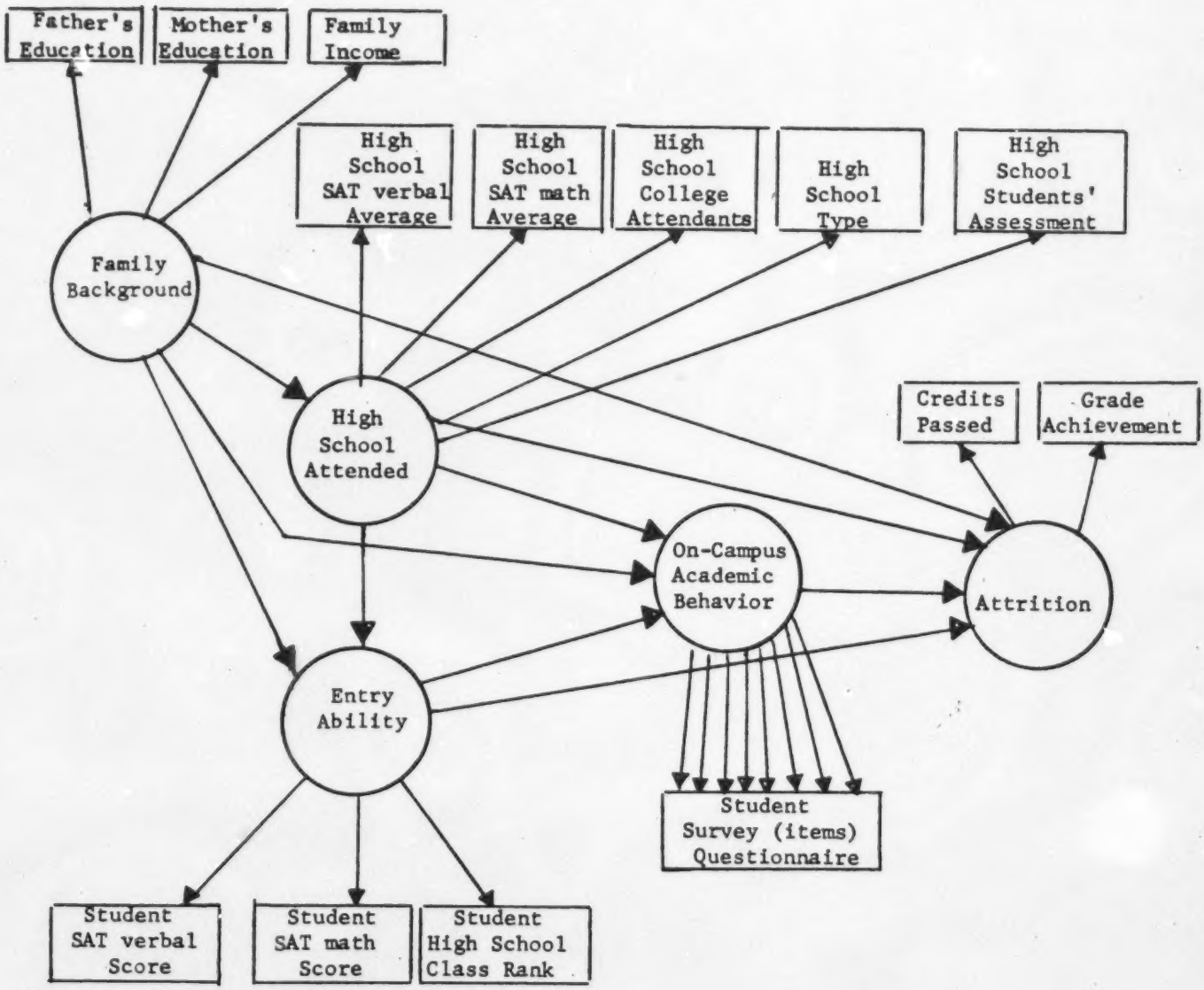

Figure 1

Indicators of Proposed Causal Model on Black Student Attrition

were measured by proposed indicator variables which are given in the rectangular blocks in Figure 1. In the figure for example, the latent variable entry ability is measured by three indicator variables; (1) student SAT verbal score; (2) student SAT math score; and (3) student high school class rank. A one-way arrow pointing from one latent variable to another suggests a non-reciprocal causal relationship.

The sample was comprised of 80 black students who were members of the University of Pittsburgh's University-Community Educational Program (U-CEP) 1976-77 and 1977-78 entering freshman classes. The total number of students entering U-CEP for these two classes was 417. Students in this sample were selected on the the basis of two criteria; (1) those who responded to the two questionnaires that were employed in the study; coupled with (2) those for whom complete high school background data was available.

U-CEP students receive a special admission into the University because of their low academic entry levels. These levels are assessed as being too low to be admitted as a regular student to the University of Pittsburgh. In Table 1 a comparison of the entry levels of U-CEP students to that of the regularly admitted student is presented.

Table 1

Academic Entry Levels of U-CEP and Regularly Admitted Students
(1976-1977 Freshmen Classes)

Ability Indicators	U-CEP	Regular Admits
High School Class Rank (average)	Upper (2/5) 60th percentile	Upper (1/5) 82nd percentile
SAT Scores (average verbal and math)	710	1010

The ranges of SAT scores and high school class ranks for this sample are presented in Tables 2 and 3. Over seventy percent of the students had SAT verbal and math scores below 400. Fifty-five percent of the students fell at or below the lower 3/5ths in their high school class ranks. Only fourteen percent of the students graduated in the upper 5th of their class.

Table 2

Range of SAT Scores of U-CEP Samples
(1976-1977 N=80)

	SAT Verbal		SAT Math	
Range	Percent	Cumulative Percent	Percent	Cumulative Percent
500 - 550	4	100	4	100
450 - 499	7	96	5	96
400 - 449	15	89	16	91
350 - 399	21	74	32	75
300 - 349	33	53	21	43
250 - 299	13	20	18	22
200 - 249	7	7	4	4

Table 3

Range of High School Class Ranks of U-CEP Sample
(1976-1977 N=80)

Range	Percent	Cumulative Percent
1/5	14	100
2/5	31	86
3/5	32	55
4/5	14	23
5/5	9	9

The degree these students expected upon entry is shown in Table 4 to be high. Only twenty percent of the students expressed a desire to terminate their education at the Bachelor degree level. Thirty-five percent of the students expressed a desire to obtain a Master's degree, twenty-one percent a professional degree, and twenty-four indicated a desire for a Doctoral degree.

Table 4

Degree Expected of U-CEP Sample
(1976-1977, N=80)

Degree	Percent	Cumulative Percent
Doctoral	24	100
Professional	21	76
Master's	35	55
Bachelor's	20	20

The levels of family income and parental education of the sample are presented in Tables 5 and 6. Fifty-six percent of the students' family income levels fell below $12,000 with twenty-six percent falling below the $6,000 income level. The majority of the parents were at least high school graduates, but for both the father and mother, over twenty percent had less than a high school education, and only nine percent were college graduates.

Table 5

Levels of Family Income of U-CEP Sample
(1976-1977, N=80)

Income Levels	Percent	Cumulative Percent
$25,000 +	13	100
$18,000 - $24,000	5	87
$15,000 - $17,999	15	82
$12,000 - $14,999	11	67
$ 9,000 - $11,999	12	56
$ 6,000 - $ 8,999	18	44
Less than $6,000	26	26

Table 6

Levels of Parental Education of U-CEP Sample
(1976-1977, N=80)

Educational Levels	Father Percent	Mother Percent
College graduate	9	9
Some college	5	12
High school graduate	58	57
Less than a high school graduate	28	22

The type of high school attended by the students is presented in Table 7. All but fourteen percent of the students attended public high schools, with forty-five percent having attended public inner-city schools, and forty-one percent coming from public suburban or rural schools.

Table 7

Types of High School Attended of U-CEP Sample
(1976-1977, N=80)

Type of School	Percent
Private or parochial	14
Public suburban or rural	41
Public inner-city	45

Instrumentation

The model proposed in the study utilized several indicator variables to measure the latent variables. A substantial amount of measurement error can be introduced into the proposed model by any given indicator variable. This problem may be alleviated through the use of multiple indicators for each latent variable. The LISREL technique employs a factor analytic technique in measuring the latent variables. This use of multiple indicators enables one to extract components of each measure related to a common dimension. Unlike factor analysis techniques which are exploratory, LISREL uses confirmatory solutions which allow researchers to specify, a priori, the relationships between the measures and latent variables. With this factor analytic approach measures do not have to be pure indicators of theoretical variables because only the shared variance of measures within a dimension is extracted. The latent variables and the corresponding indicator variables of the proposed model are shown in Table 8.

Table 8

Latent and Indicator Variables of the Proposed Attrition Model

Family Background	Latent Variable
(1) Father's education	
(2) Mother's education	(indicator variables)
(3) Family income	
High School Attended	Latent Variable
(4) High school's average SAT verbal score	
(5) High school's average SAT math score	
(6) High school's percent of college attendance	(indicator variables)
(7) High school type	
(8) High school's student assessment	
Entry Ability	Latent Variable
(9) Student's SAT verbal score	
(10) Student's SAT math score	(indicator variables)
(11) Student's high school class rank	
On-Campus Academic Behavior	Latent Variable
(12) Student report on campus academic behavior (Survey Questionnaire)	(indicator variables)
:	
(19)	
Attrition	Latent Variable
(20) Credits passed	
(21) Grade achievement	(indicator variables)

Indicator Variables

Information on family income and parental education was obtained from the University of Pittsburgh's Freshman Questionnaire. The Freshman Questionnaire is sent to all entering freshman students at the University. It was developed by the University's Office of Institutional Research and Planning and is the mechanism used to obtain students'

personal and socioeconomic background data. Response to the Questionnaire is voluntary. For the 1976-1977 cohorts, the response rate was approximately fifty-nine percent.

Information on the high schools was obtained primarily from A Guide to Middle State Schools (Crawford, 1979). Most of the students in the U-CEP program attended Pennsylvania high schools. The specific data that were used in the high school's assessment were the student body's SAT verbal score average, SAT math score average, and the percentage of graduating students who plan to attend either a four-year institution or a two-year college. A two to one weighting was given to the percentage of students planning to attend a four-year institution vs a two-year college.

The type of high school attended was rated in three categories ranging from Low (1) to High (3). The categories used for the study were (1) public inner-city schools; (2) public suburban or rural schools; and (3) private or parochial schools.

High schools were also assessed in terms of students' evaluation of their academic preparedness for post secondary education. This assessment was based on student responses to a U-CEP Survey Questionnaire which was developed by the U-CEP staff to obtain the students' assessment of their on-campus academic behavior, academic preparedness, and the University environment. The U-CEP Survey Questionnaire was mailed in the Spring of 1979 to all U-CEP students, both active and inactive, and an additional mailing was done after a six month period. Response to the Questionnaire was voluntary, and students were identified via a coding system that was explained in the directions. For the 1976-1977 cohort the response rate was approximately forty percent.

In the Questionnaire, students were asked to respond to items on a scale ranging from 1 (rarely) to 5 (almost always). The sum of students' total responses across five items was used in their high school evaluation. The items are shown in Table 9.

Measures of students' entry ability were obtained from students' high school admission records for the University. Indicator variables taken from these records were students' high school class rank and their SAT verbal and math scores. High school class rank was obtained by dividing the students' class standing by the size of the graduating class. A converted high school rank was used which takes into account the student's varying class sizes. This was determined through the use of a formula conversion table developed by the Educational Testing Service.

Table 9

Questionnaire Items Used to Evaluate High School Academic Preparedness

Questionnaire Items
1. My high school prepared me to write college level papers.
2. My high school prepared me to handle math related courses.
3. My high school prepared me to handle science related courses.
4. My high school prepared me to study properly.
5. My high school prepared me to fulfill overall college requirements.

Scholastic Aptitude Test Scores (SAT) are from the College Entrance Examination Boards (CEEB).

Items from the U-CEP Survey Questionnaire were also used to measure students' on-campus academic behavior. Eight items were included and each was used as a separate indicator of students' behavior. The selected items are shown in Table 10.

Table 10

Questionnaire Items Used to Measure
On-Campus Academic Behavior

Questionnaire Items
1. I completed required homework adequately and on time.
2. I discussed class problems with instructors.
3. I worked with other students when encountering course difficulties.
4. I attended class regularly.
5. I used academic support services, such as tutoring and workshops when needed.
6. I asked questions in class when I did not understand or needed further clarification.
7. I studied carefully and completely for all tests.
8. I put forth my maximum effort to succeed in class.

College grade achievement and credits passed were used as indicators of student attrition. They were selected as measures of attrition because the primary reason for the attrition of U-CEP students, like many specially admitted students, is poor academic performance. Grade achievement at the University of Pittsburgh was determined by students' cumulative quality point average (QPA). At the University, QPA is based of the following values: A=4.00, B=3.00, C=2.00, D=1.00, F=0.00. Credits passed were measured in terms of students' average credits passed per

term. A student at the University is required to maintain a 2.00 QPA (C average), and pass a minimal average of 12 credits per term to remain in good academic standing. Students not in good academic standing are subject to dismissal.

Since most U-CEP students are permitted to stay in the U-CEP program for at least two years, even with a poor academic standing, in this study grade achievement and credits passed were based on the students' standing after completion of their second year of attendance.

Analysis

The primary goal of the LISREL technique is confirmatory in terms of substantiating theory and exploratory in terms of refining the initial theory on the basis of empirical data. The LISREL Model consists of two parts, the structural equation model and the measurement model. The structural equation model is used to specify the causal relationships among the latent variables and is used to describe the causal effects and the amount of unexplained variance. The measurement model specifies how well the latent variables or hypothesized constructs are measured in terms of the observed variables. The general model is presented by Joreskog (1979) as: A system of linear structural equation relations:

$$\beta\underline{\eta} = \Gamma\underline{\xi} + \underline{\zeta} \qquad (1)$$

of latent dependent and independent variables, with random vectors of $\underline{\eta}$ (m x 1) and $\underline{\xi}$ (n x 1), respectively; where β (m x m) and Γ (m x n) are coefficient matrices and $\underline{\zeta}$ (m x 1) is a random vector of residual errors (see Figure 6, (Appendix A) and Table 11 for the specific

representation of this general model as it relates to the proposed attrition model in this study). In the study m = 4, represents the number of latent dependent variables, and n = 1, represents the number of latent independent variables.

Since the latent variables are unobservable, $\underline{y}$ (p x 1) and $\underline{x}$ (q x 1) are vectors of the indicator variables, which are given in the measurement model as:

$$\underline{y} = \Lambda_y \ \underline{\eta} + \underline{\varepsilon} \tag{2}$$

and

$$x = \Lambda_x \ \underline{\xi} + \underline{\delta} \tag{3}$$

where $\underline{\varepsilon}$ (p x 1) and $\underline{\delta}$ (q x 1) are vectors of the errors of measurement in $\underline{y}$ and $\underline{x}$. In the proposed model, p = 18 and q = 3.

The measurement model is a factor analysis model which can be given as:

$$\underline{z} = \Lambda \underline{f} + \underline{e} \tag{4}$$

where $\underline{z}$ is a vector of the indicator variables $\underline{y}$ and $\underline{x}$, Λ are coefficients representing the factor loadings on the latent variables $\underline{\eta}$ and $\underline{\xi}$, $\underline{f}$ is a vector of latent variables or common factors, and $\underline{e}$ is a vector of measurement errors or unique factors.

From the general LISREL Model the structural equations and related hypotheses in this study are presented as follows:

$$\eta_1 = \gamma_1 \ \xi_1 + \zeta_1$$

(Family background has a direct effect on the high school attended.)

$$\eta_2 = \gamma_2 \ \xi_1 + \beta_1 \ \eta_1 + \zeta_2$$

(Family background and high school attended have a direct effect on student's entry ability.)

$$\eta_3 = \gamma_3 \ \xi_1 + \beta_2 \ \eta_1 + \beta_3 \ \eta_2 + \zeta_3$$

(Family background, high school attended, and entry ability have a direct effect on students' on-campus academic behavior.)

$$\eta_4 = \gamma_4 \xi_1 + \beta_4\eta_1 + \beta_5\eta_2 + \beta_6\eta_3 + \zeta_4$$

(Family background, high school attended, entry ability, and on-campus academic behavior have a direct effect on attrition.)

Procedure and Results

In substantiating the hypothesized model the major task was to estimate the parameters of the model and determine the goodness-of-fit of the model to the sample data. On the basis of this fit, the proposed model was evaluated as a plausible representative of the causal structure underlying the observed indicator variables.

Several steps were utilized to test the fit of the model. Initially, the input data were transformed into a format acceptable for the LISREL computer program (Joreskog and Sorbom, 1978). LISREL is designed to accept data in various forms, and for this study a correlation matrix was used as the input mechanism. It was derived using the BMDP correlation program (Engleman, Frane, and Jennrich, 1979).

From this input data specifications of the two sets of relationships, measurement and structural, were provided which allowed the LISREL computer program to generate all unknown parameters. This involved the translation of model specifications presented in Figure 6 (Appendix A) into two matrix equations (Appendix B) representing the structural and measurement portions of the theoretical model. Unknown parameters are defined by the LISREL program as free parameters, as opposed to fixed parameters that have been assigned values a priori.

Table 11

Proposed Model Specifications

ξ_1 = Family background	latent independent variable
η_1 = High school attended	latent dependent variables
η_2 = Entry ability	.
η_3 = On-campus academic behavior	.
η_4 = Attrition	.
x_1 = Father's Education (FE)	indicator variables of ξ_1
x_2 = Mother's Education (ME)	.
x_3 = Family income (FI)	.
y_1 = High school SAT verbal average (HV)	indicator variables of η_1
y_2 = High school SAT math average (HM)	.
y_3 = High school college attendants (HC)	.
y_4 = High school type (HT)	.
y_5 = High school students' assessment (HS)	.
y_6 = Student SAT verbal score (SV)	indicator variables of η_2
y_7 = Student SAT math score (SM)	.
y_8 = Student high school class rank (SR)	.
y_9 = Student Survey Questionnaire (Q_5^1 Q_6^2 Q_7^3 Q_8^4)	indicator variables of η_3
.	.
.	.
y_{16} =	.
y_{17} = Credits passed (CR)	indicator variables of η_4
y_{18} = Grade Achievement (QP)	.

ξ = xi

η = eta

On the basis of these equations the LISREL computer program was used to test the hypothesized model which will be referred to as model 1. The standardized solution for model 1 is given in Figure 2 This solution gives the beta (β) and gamma (γ) parameter estimates in terms of standardized latent variables in which they are scaled to unit variance. The lamba (λ) coefficients which are the factor loadings of the observed variables, remain in the standardized metric.

An examination of the standardized solution shows the relative magnitude of the observed variables on each of the latent variables, and the relative strength of the relationship among these latent variables. For example, the lambda coefficients for the indicators of the latent variable family background were: (1) father's education (λ_{19} = .59); mother's education (λ_{20} = .91); and family income (λ_{21} = .37). The strength of the relationship of family background to other latent variables are given by the gamma (γ) coefficients. They are presented in Table 12. The gamma coefficients indicate a minimal relationship between family background and the latent variables, high school attended, entry ability, on-campus academic behavior, and attrition. In Table 13

Table 12

Estimates of the Gamma Parameters

1. The effect of family background on the high school attended (γ_1 = .02).
2. The effect of family background on entry ability (γ_2 = -.06).
3. The effect of family background on on-campus academic behavior (γ_3= -.04).
4. The effect of family background on attrition (γ_4 = -.13).

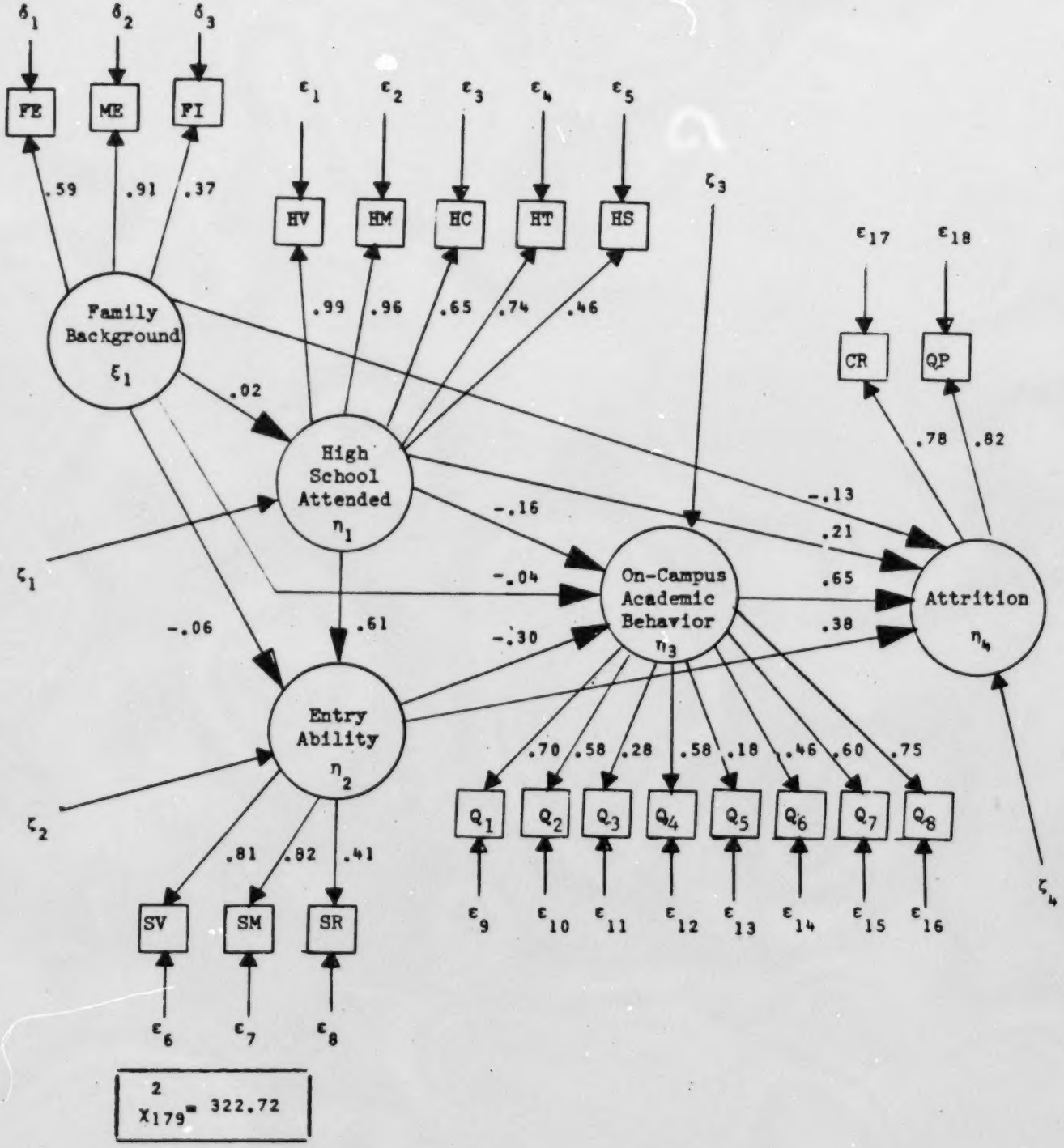

Figure 2

Standardized Solution for Model 1

the estimates for the beta parameters are presented. The effect of high school attended on entry ability, the effect of entry ability on attrition, and the effect of on-campus academic behavior on attrition were significant at the .05 alpha level.

Table 13

Estimates of the Beta Parameters

1. The effect of high school attended on entry ability (β_1 = .61)*
2. The effect of high school attended on on-campus academic behavior (β_2= -.16)
3. The effect of high school attended on attrition (β_4 = .21)
4. The effect of entry ability on on-campus academic behavior (β_3= -.30)
5. The effect of entry ability on attrition (β_5= .38)*
6. The effect of on-campus academic behavior on attrition (β_6= .65)*

* $p \leq .05$

An evaluation of the fit of the model was based on the χ^2 value generated on the basis of the theoretical model and the sample data. For model 1 the χ^2 goodness-of-fit test yielded a χ^2 value of 322.72 with 179 degrees of freedom. This was not an acceptable fit because a large χ^2 value with respect to the degrees of freedom indicates that the model does not adequately represent the causal process generated by the sample data (Bentler, 1980).

Measurement Analysis

Since the purpose of this study was to develop and test a causal model on student attrition, steps were made in this testing procedure to determine if problems existed in attempts to measure each of

the hypothesized latent variables. If errors could be identified, modifications could be made to the initial model to help arrive at an overall best fitting model in terms of the underlying theory.

The examination of the measurement portion of the model began with a residual analysis. In the proposed model, large residuals for a given indicator variable may contribute to the inadequate fit of the model because of measurement problems. A summary of the residual analysis for model 1 is presented in Table 14. Included were residuals whose absolute values were greater than or equal to .100. A total of 124 large residual numbers or 62 unique pairs were identified. The variable SR (student's high school rank) had large residual values with 12 of the other 20 indicator variables. Q_3 (an aspect of students' on-campus academic behavior) had large residual values with 11 of the other 20 indicator variables. These variables were investigated for possible measurement problems.

The reliability of the students' high school rank was not considered a measurement problem because the information was obtained directly from the students' high school records. What was considered as a possible measurement problem was its construct validity as related to entry ability. The sample of U-CEP students used in the study attended a wide variety of high schools, many of which were inner-city public schools. The meaning of the high school rank as a measure of entry ability is often dependent on the school from which that rank was obtained. For example, the rank of a student graduating in the upper fifth of an inner-city public school may have a different meaning or reflect a different level of entry ability as compared to the same rank of a student who attended a private school. The student from the inner-

Table 14

Summary Residual Analysis for Model 1

Indicator Variable	Number of Residuals $\geq \lvert .100 \rvert$	Residuals $\geq \lvert .100 \rvert$ after removal of SR, Q_3	Residuals $\geq \lvert .100 \rvert$ after removal of SR, Q_3, HS, Q_2, Q_2, Q_5
HV	3	2	0
HM	3	2	0
HC	7	6	4
HT	8	6	5
HS	8	7	-
SV	4	4	4
SM	4	3	3
SR	12	-	-
Q_1	5	3	1
Q_2	7	8	-
Q_3	11	-	-
Q_4	5	4	1
Q_5	5	5	-
Q_6	7	4	1
Q_7	5	2	1
Q_8	2	2	1
CR	3	2	2
QP	2	1	1
FE	7	5	2
ME	9	8	4
FI	7	6	2
TOTAL	124/2=62	80/2=40	32/2=16
	χ^2 = 322.72 df = 179	χ^2 = 195.50 df = 142	χ^2 = 125.44 df = 94

city school may not have been exposed to the same courses or degree of academic competition.

The size of a graduating class can also affect the rank of the student, but for this study this fact was taken into account through the use of a rank conversion table. However, another possible contributing factor to measurement problems, as related to high school rank, may have been the sample used in the study. Although an examination revealed substantial variability for this sample in terms of ranks, black students who exhibit higher levels of ability in their high school performance are rarely placed in the U-CEP program.

Concerns about the validity of this variable were further supported by the fact that its relative influence on the construct, entry ability was small ($\lambda = .41$) compared to that of students' SAT verbal ($\lambda = .81$) and math scores ($\lambda = .82$). This variable was therefore eliminated from the initial hypothesized model.

Q_3 on the U-CEP Survey Questionnaire asked students to what extent they worked with other students when encountering course difficulties. This question, like others developed to measure on-campus academic behavior, implied that answers like "almost always" reflected positive campus behavior as opposed to "rarely or sometimes." However, for this particular question, working with other students is highly dependent on the amount and type of difficulty encountered in classes and the personal study habits of the individual. Because of this, it is difficult to determine the meaning of responses to this question, particularly when compared to other questions such as attending class regularly, which may have more relevance in terms of positive academic campus behavior. This variable also showed a relatively low factor

loading on the construct, on-campus academic behavior (λ =.28), and was subsequently eliminated from the study.

The elimination of the indicator variables SR and Q_3 resulted in a reduction of the number of large residuals from 124 to 80. This resulted in a change in χ^2 value from χ^2_{179}=322.72 to χ^2_{142}=195.50. The difference was significant at the .05 alpha level. After the elimination of these indicators, the residual analysis continued to determine if additional variable elimination could improve the fit of the model. The remaining indicator variables were viewed in terms of their number of large residual pairings and the lambda values of the constructs. The variables HS (students' assessment of their high school), Q_2 and Q_5 (aspects on on-campus academic behavior), and ME (mother's education) were investigated.

HS had the highest residual pairing and lowest lambda value of the variables designed to indicate an assessment of the high school attended. It was obtained from student responses to the U-CEP Questionnaire on areas relating to whether their high school prepared them to write or study properly, handle math and science related courses, or fulfill overall college requirements. Other measures of the high school were obtained from the Middle States report on high schools and may have reflected a more reliable and valid assessment of the high school attended. This variable was eliminated from the study.

Q_2 and Q_5 of the Questionnaire were also eliminated. They had the largest remaining residual pairings and the lowest relative influence in measuring on-campus academic behavior. The questions related to behavior such as discussing class problems with instructors and using academic support services such as tutoring. Again, the validity

of the responses on these questions in terms of positive academic behavior would appear to be highly individualized, in terms of students' type of academic problems and particular ways of handling them.

Another variable indicator showing a substantial number of large residual pairings was ME (mother's education). This variable, however, showed the highest influence on the construct, family background. In addition, there was no evidence to indicate that its assessment would be any less reliable or valid than that of family income or father's education. All measures were obtained from students' voluntary responses to the University of Pittsburgh's Freshmen Survey. For these reasons, this indicator was not eliminated.

Five variables were eliminated in the residual analysis, which resulted in a reduction of the number of large residuals to 32 or 16 unique pairs. This reduction resulted in a χ^2 value of 125.44 with 94 degrees of freedom, an improvement in the fit that was significant at the .05 alpha level. The specific indicators eliminated were:

1. The high school as assessed by the student.
2. Student's high school class rank.
3. Q_2 ("I discussed class problems with instructors").
4. Q_3 ("I worked with other students when encountering course difficulties").
5. Q_5 ("I used academic support services, such as tutoring and workshops when needed").

Model 2, presented in Figure 3, shows the standardized solution after the residual analysis.

The second technique used in attempts to improve the measurement portion of the model was to conduct a first-order derivative analysis. Here, first-order derivatives that were computed for the covariances of

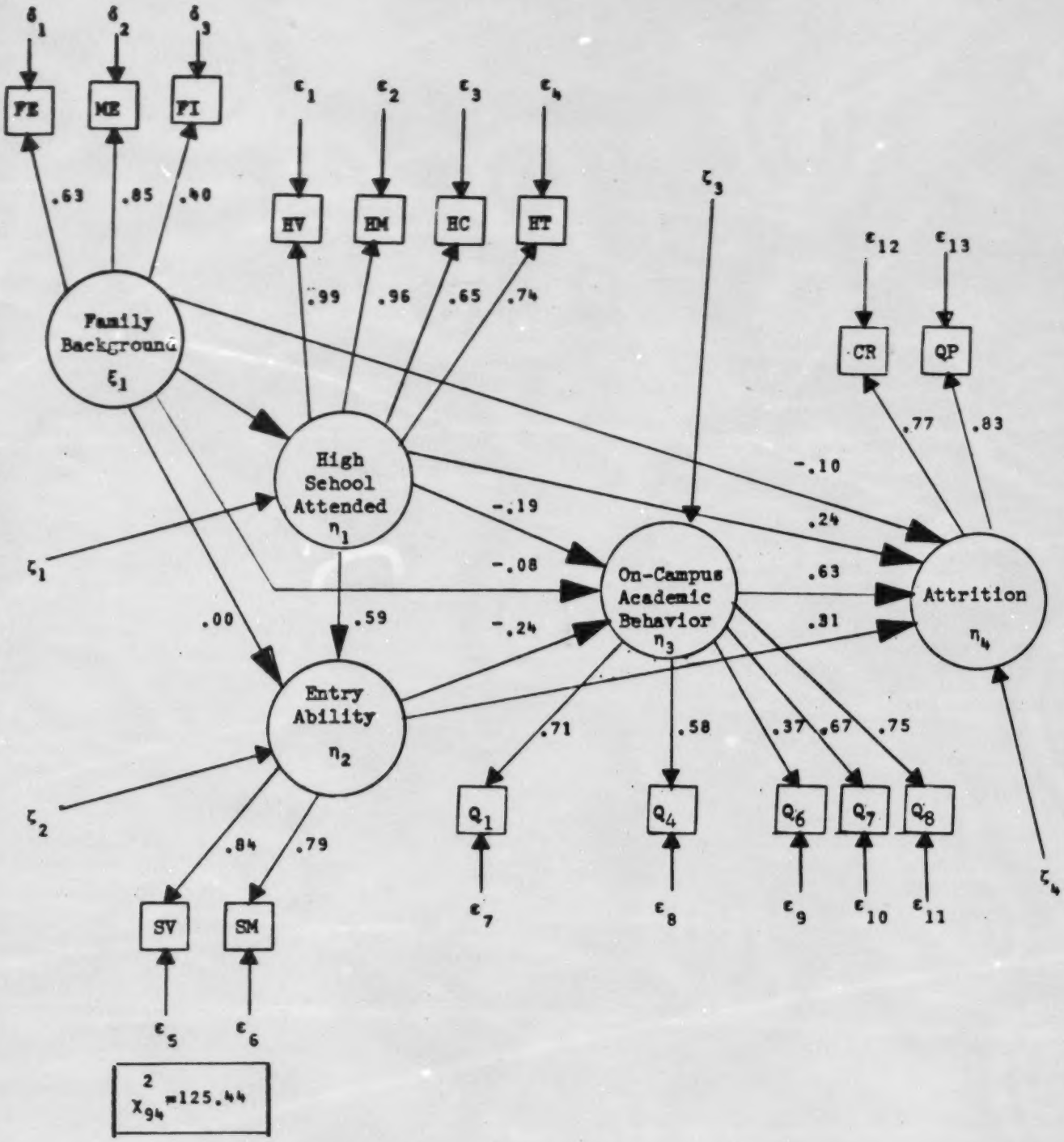

Figure 3

Standardized Solution for Model 2

Θ_ε and Θ_δ were examined to determine if the allowance of correlated errors in the measurements could result in an improvement in the model. Investigated were indicators in which correlated measurement error could be expected to occur. On this basis, three sets of measures were identified with large, first-order derivatives. They were the sets, high school college attendants and high school math average, high school college attendants and high school type, and high school verbal average and high school type. Because these high school assessments were derived from the same measurement process, there was reason to believe that correlated measurement error could have occurred.

Initially, the variables high school college attendants and high school math average were allowed to covary. This resulted in a change of the χ^2 value from 125.44 to 117.41, a significant improvement for a drop of one degree of freedom. After allowing these indicators to covary the first-order, derivatives were reexamined and the set, high school college attendants and high school type had the next highest derivative. Correlations were allowed between these indicators and again, resulted in a significant improvement at the .05 alpha level in the χ^2 value of 109.26 with 92 degrees of freedom. There were no other significant sets identified, and at this point changes in the measurement portion of the model were concluded.

The final results of changes in the initial hypothesized model are presented in Figure 4. Model 3 shows a fit that is substantially improved as compared to models 1 and 2. The model, however, shows that little changes were made in the beta and gamma parameters as a result of changes in the measurement portion of the model. A summary of the standardized solutions for model 1, model 2, and model 3 are presented in Table 15.

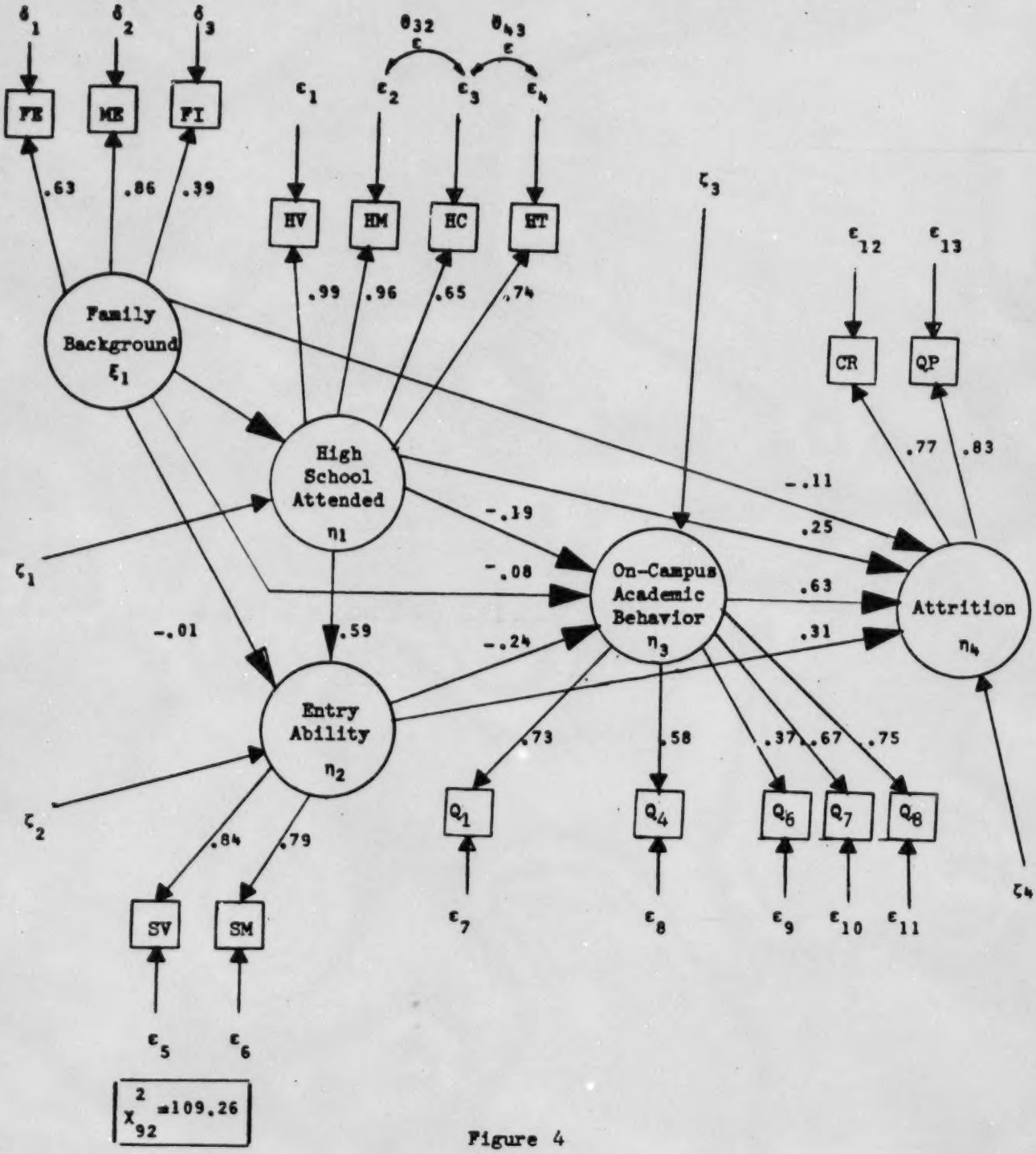

Figure 4

Standardized Solution for Model 3

Table 15

Standardized Solution Parameter Estimates for Models 1, 2, and 3

Parameters	Model 1	Model 2	Model 3
λ_1 (HV)	.997	.999	.989
λ_2 (HM)	.963	.963	.972
λ_3 (HC)	.646	.646	.654
λ_4 (HT)	.738	.735	.742
λ_5 (HS)	.455	-	-
λ_6 (SV)	.808	.843	.843
λ_7 (SM)	.817	.793	.791
λ_8 (SR)	.406	-	-
λ_9 (Q_1)	.702	.725	.725
λ_{10} (Q_2)	.583	-	-
λ_{11} (Q_3)	.278	-	-
λ_{12} (Q_4)	.581	.574	.575
λ_{13} (Q_5)	.179	-	-
λ_{14} (Q_6)	.457	.368	.368
λ_{15} (Q_7)	.602	.668	.667
λ_{16} (Q_8)	.752	.751	.752
λ_{17} (CR)	.778	.766	.772
λ_{18} (QP)	.821	.834	.828
λ_{19} (FE)	.594	.634	.626
λ_{20} (ME)	.911	.852	.864
λ_{21} (FI)	.373	.400	.394
β_1	.605	.594	.592
β_2	-.163	-.188	-.192
β_3	-.303	-.244	-.243
β_4	.214	.241	.247
β_5	.377	.308	.307
β_6	.646	.626	.627
γ_1	.022	.021	.040
γ_2	-.061	.003	-.012
γ_3	-.039	-.080	-.077
γ_4	-.130	-.096	-.106
	$\chi^2_{179} = 322.72$	$\chi^2_{94} = 125.44$	$\chi^2_{92} = 109.26$

As mentioned previously, parameter estimates of the lambda (λ) coefficients represent the factor loadings of the observed variables for the latent variables. Lambda (λ) for example was the loading of the high school SAT verbal average on the latent variable, high school attended. For models 1, 2 and 3, the lambda values were .997, .999, and 989, respectively. Recall that the parameter estimates of the beta (β) and gamma (λ) coefficients represent the strength of the relationship among the hypothesized constructs. This relationship is referred to in this study as the effect of one construct on another. Beta (β) for example, represents the effect of the high school attended on entry ability. For models 1, 2, and 3 the estimates were .603, .594, and .592. Gamma (λ) represents the effect of family background on the high school attended, and its values for models 1, 2, and 3 were .022, .021, and .040, respectively.

Structural Analysis

In order to adequately test the model proposed in this study, it was necessary to not only examine the measurement portion of the model, but also the structural portion. The structural analysis helps to determine if modifications should be made to the structure of the initial hypothesized model. This analysis is most critical, considering that the structural portion of the model should reflect what is known conceptually.

The first step in this procedure was to examine the z-tests generated by the LISREL program for the beta and gamma parameters. This was done to determine which parameters were significantly different from zero. The parameters found to be significant at the .05 alpha level were β_1 (the effect of high school attended on entry ability), β_5 (the effect of entry ability on attrition), and β_6 (the effect of on-campus academic

behavior on attrition). β_3 (the effect of entry ability on on-campus behavior), and β_4 (the effect of high school attended on attrition) showed a non-significant influence.

None of the gamma parameters, γ_1, γ_2, γ_3, γ_4, showed any significant relationship to any of the independent latent variables. These parameters represented the effects of students' family background on the high school attended; entry ability; on-campus academic behavior; and attrition. The lack of significant relationships with other latent variables indicated that family background could be dropped from the model.

With the elimination of family background, the construct high school attended became a latent independent variable. Specifications for this new hypothesized model, which is referred to as model 4, are presented in Figure 7 (Appendix C) and the matrix equations are presented in Appendix D. The standardized solution (Figure 5) yielded a χ^2 value of 59.99 for 57 degrees of freedom, representing a significant improvement at the .05 alpha level in the fit from model 3 to model 4.

A first-order derivative analysis was then conducted for the structural parameters. None were found to be large enough to suggest any additional changes in the structural relationships presented in model 4. Therefore, the structural analysis was terminated with model 4.

Summary

A summary of the procedures and results of the study are presented in Tables 16 and 17. In Table 16 modifications that were made in attempts to optimize the fit of the initial hypothesized model are given. In Table 17 estimates of the proposed effects for each of the resultant models are shown.

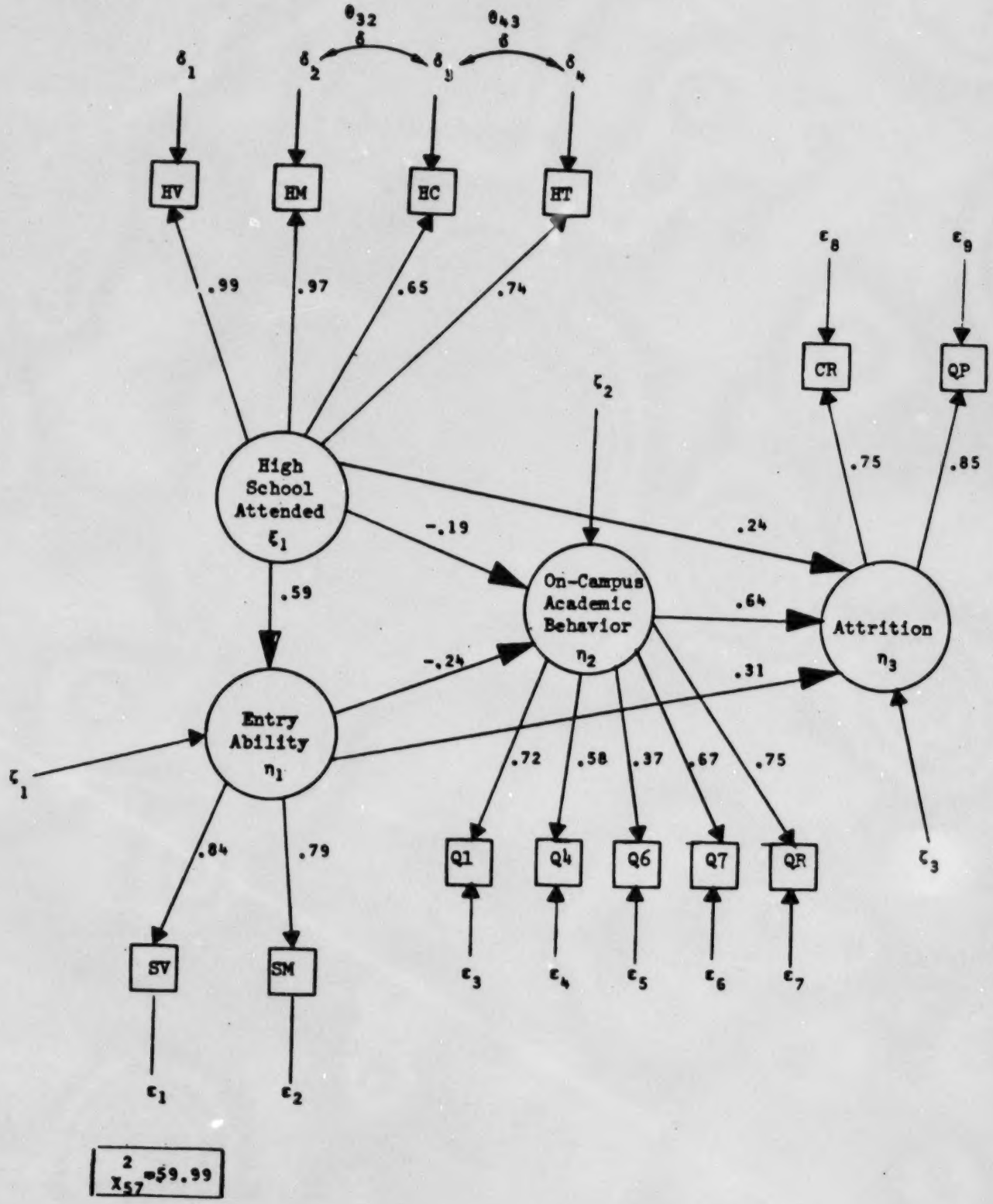

Figure 5

Standardized Solution for Model 4

Table 16

Summary of Model Fitting Procedure

Model	Estimated Parameters	Indicator Variables	χ^2	df	χ^2 Test Differences χ^2	df
1	$\beta_1\ \beta_2\ \beta_3\ \beta_4\ \beta_5\ \beta_6$ $\gamma_1\ \gamma_2\ \gamma_3\ \gamma_4$	---	322.72	179		
2	$\beta_1\ \beta_2\ \beta_3\ \beta_4\ \beta_5\ \beta_6$ $\gamma_1\ \gamma_2\ \gamma_3\ \gamma_4$	HS, SR, Q_2 Q_3, Q_5	125.44	94	197.28	75*
3	$\beta_1\ \beta_2\ \beta_3\ \beta_4\ \beta_5\ \beta_6$ $\gamma_1\ \gamma_2\ \gamma_3\ \gamma_4$ $\theta_\varepsilon\ 3,\ 2\ \theta_\varepsilon\ 4,3$	HS, SR, Q_2 Q_3, Q_5	109.26	92	16.18	2*
4	$\beta_1\ \beta_2\ \beta_3$ $\gamma_1\ \gamma_2\ \gamma_3$ $\theta_\varepsilon\ 3,2\ \theta_\varepsilon\ 4,3$	HS, SR, Q_2 Q_3, Q_5	59.99	57	49.27	35*

*$p \leq .05$

Table 17

Summary of Causal Model Results

	Model 1	Model 2	Model 3	Model 4
Effect of family background				
on high school attended	.02	.02	.04	-
on entry ability	-.06	.00	-.01	-
on on-campus academic behavior	-.04	-.08	-.08	-
Effect of high school attended				
on entry ability*	.61	.59	.59	.59
on on-campus academic behavior	-.16	-.19	-.18	-.19
on attrition	.21	.24	.24	.24
Effect of entry ability				
on on-campus academic behavior	-.30	-.24	-.24	-.24
on attrition *	.38	.31	.31	.31
Effect of on-campus academic behavior				
on attrition*	.65	.63	.63	.64
Unexplained variance				
Ψ_1 high school attended	1.00	1.00	.998	-
Ψ_2 entry ability	.632	.647	.649	.649
Ψ_3 on-campus academic behavior	.821	.843	.842	.847
Ψ_4 attrition	.563	.588	.584	.600
χ^2	322.72	125.44	109.26	59.99
degrees of freedom	179	94	92	57

*$p \leq .05$

Model 1 represents the initial hypothesized model. For this model the χ^2 value was 322.72 with 179 degrees of freedom. As mentioned previously, a large χ^2 value compared to the degrees of freedom indicates an inadequate fit. If the χ^2 statistic is small compared to the degrees of freedom, it indicates that the model is a plausible representative of the causal process as indicated by the sample data. For model 1 the χ^2 value did not indicate a good fit.

Modifications to model 1 resulted in model 2. The modifications were the elimination of five indicators of the latent variables. These indicators were students' assessment of their high school, students' high school rank, and three questions relating to students' on-campus academic behavior. On the basis of a residual analysis these indicators had been assessed as having measurement problems in terms of reliability or validity. The elimination of these indicators resulted in a χ^2 value of 125.44 for 94 degrees of freedom. This change was significant at the .05 alpha level.

Additional modifications resulting in model 3, were made on the basis of a first-order derivative analysis in which correlated measurement errors were allowed for specified indicators. The indicators that were allowed to covary were the sets, high school college attendants and high school math average, and high school college attendants and high school type. Again, this resulted in a significant improvement at the .05 alpha level for the χ^2 value of 109.26 for 92 degrees of freedom.

The changes which were reflected in models 2 and 3 represented modifications in the measurement portion of the hypothesized model. An additional analysis was conducted on the structural portion of the model. In this analysis a z-test was conducted on the beta and gamma parameters

to determine if any of the proposed relationships were not statistically significant. This analysis showed that the construct, family background showed no significant relationship to any of the other constructs.

Model 4 represented changes in the structural model as a result of the elimination of the construct family background. All modifications terminated with model 4 and the final χ^2 value of 59.99 for 57 degrees of freedom represented both a significant improvement at the .05 alpha level between model 3 and model 4, and an overall good fit of the hypothesized model on the basis of the χ^2 value and corresponding degrees of freedom.

In models 1, 2, 3, and 4 the significant relationships, indicated in Table 17 are: (1) the effect of high school attended on entry ability (.61, .59, .59, .59); (2) the effect of entry ability on attrition (.38, .31, .31, .31); and (3) the effect of on-campus academic behavior on attrition (.65, .63, .63, .64). These values are estimates of the beta and gamma parameters and represent the magnitude of these effects. It should be noted that the values remained fairly constant throughout modifications to model 1, indicating that changes in the measurement portion of the model has a minimal effect on estimates of the structural parameters.

The unexplained variance (psi value ψ) for each of the constructs is also presented in Table 17 for each of the models. In models 1, 2, and 3 high school attended was proposed as being affected by students' family background. The psi value for high school attended is approximately 1.00 across these models, indicating that no variation in the construct is explained by family background. This is a direct result of the family background construct being the only latent variable

proposed to have an effect on the high school attended, and estimates of this effect are given as .03, .02, and .04 for models 1, 2, and 3 respectively. In model 4, high school attended became a latent independent variable as a result of the elimination of the family background construct.

Entry ability was hypothesized to be affected by family background and high school attended. The unexplained variance in this construct is shown in Table 17 to be .632, .647, .649, and .649 across the four models. Since the effect of family background on entry ability was found to be nonsignificant, the explained variance was accounted for primarily by the effects of high school attended on entry ability, which was significant at the .05 alpha level.

On-campus academic behavior was proposed to be affected by the family background, high school attended, and entry ability. These variables had a negative impact on this construct across the models, and as a result the unexplained variance was .821, .843, .842, and .847. Attrition was hypothesized to be affected by all of the other constructs, family background, high school attended, entry ability, and on-campus academic behavior, with family background being excluded from model 4. The unexplained variance in this construct was .563, .588, .584, and .600, for models 1, 2, 3, and 4. As mentioned previously, entry ability had an effect at the .05 alpha level and on-campus academic behavior at the .05 level, on attrition.

The psi values like the gamma and beta values remained constant throughout modifications to the measurement portion of the initial model, as reflected by models 2 and 3, and modifications to the structural portion as reflected by model 4.

Discussion

The purpose of this study was to develop and test a hypothesized model of black student attrition in a large urban university. A causal model was proposed in order to test the strength of the relationships among the constructs and the hypothesized direction of these relationships in terms of student attrition.

The overall approach in the study was to:

1. Outline the theoretical model to be examined, based on familiarity with the area and previous research on student attrition.

2. Translate the theoretical model into an empirically testable model.

3. Test the model using the LISREL computer program to estimate the parameters and determine the goodness-of-fit of the sample data to the theoretical model.

4. Analyze and modify the hypothesized model to optimize the fit. Several hypothesized relationships were investigated. They are as follows:

    a. Family background has a direct effect on students' high school attended, entry ability, on-campus academic behavior, and attrition.

    b. The high school attended has a direct effect on students' entry ability, on-campus academic behavior, and attrition.

    c. Entry ability has a direct effect on students' on-campus academic behavior and attrition.

    d. On-campus academic behavior has a direct effect on attrition.

The results of the study did not support the hypotheses proposed on students' family background. Unlike many studies, significant relationships were not found between family background and high school attended, entry ability, on-campus academic behavior or attrition. Many of these studies however, were based on traditional students. Different findings between this study and others based on black students, may have

been attributed in part to the indicators used to assess family background.

In this study, the variables used in measuring students' family background, namely parental education and family income may not be the most sensitive indicators of a students' family background for assessing impact on academic success. For example, parental levels of educational aspirations and the quality of relationships with parents have been found to be influential factors on student attrition (Trent and Ruyle 1965; Hackman and Drysinger, 1970).

The results of the study also did not support the hypotheses that students' high school attended has a direct relationship to their attrition. The relationship of the type of high school attended to attrition was minimal. This finding also differed from that suggested by other researchers. Many suggest that the high school attended has a significant effect on the performance of students in college. Grant and Hoeber (1978) stated that students coming from poor school systems encounter great difficulties in post-secondary education. Those who attended public schools are considered to be at a definite disadvantage in college compared to students who attended private high schools. Since the largest proportion of the students in this study attended urban inner-city high schools, and only a few attended private schools, this may have moderated possible effects of the high school attended on attrition.

However, the high school attended had a significant relationship to students' entry ability which, in turn, had a significant relationship to attrition. This suggests that conclusions indicating the importance of students' high school attended on attrition may actually be a reflection of the importance of the high school attended on students'

entry ability. In a study conducted by Shaycoft (1967) it was concluded that the high school attended makes a significant difference in a students' cognitive development. This conclusion is supported to an extent by the findings in this study. No relationship was found between the high school attended and students' on-campus academic behavior.

Entry ability was found to have a significant relationship to student attrition. The reported relationship of this construct to attrition has varied greatly for both black and white students in higher education. Substantial controversy on the effect of entry ability has also centered on concerns over the most effective measure of student entry ability. For this study, the indicator variables SAT verbal and SAT math were found to be the more effective measures. The indicator high school rank, which has often been reported as the most effective measure of students' academic potential, was eliminated because of assessed measurement error as a result of the residual analysis, and its minimal factor loading on the construct entry ability, as compared to the students' SAT verbal and math score. It should be mentioned, however, that the students' high school rank had the highest correlation with students' credits passed and grade achievement, when compared to the SAT verbal and math scores. This may be the result of the variable high school rank measuring something other than entry ability as assessed by standardized scores, and that it was not measured with excessive error.

The failure of entry ability to relate to on-campus academic behavior and more strongly to attrition, may have been directly related to the indicators chosen to measure this construct. For example, no

measure of study habits in high school was included, however Stone and Ryan (1964) found these study habits to be related to attrition in college. Perhaps students' high school class rank and other variables that can be identified to assess past academic behavior, should be incorporated as a construct other than entry ability, to more effectively determine the effect of past academic performance on future academic performance.

Another factor affecting the relationship of entry ability to campus behavior and attrition may have been related to the particular students used in this study. For this sample, the range of ability was restricted, with a minimal number of students graduating in the upper levels of their high school class or exhibiting higher levels of SAT scores.

The construct with the greatest relationship to student attrition was their on-campus academic behavior. This initially was assessed by the following questions. (Those marked with an asterisk (*) were later dropped from the analyses.)

1. I completed required homework adequately and on time.

*2. I discussed class problems with instructors.

*3. I worked with other students when encountering course difficulties.

4. I attended class regularly.

*5. I used academic support services such as tutoring and workshops when needed.

6. I asked questions in class when I did not understand or needed clarification.

7. I studied carefully and completely for all tests.

8. I put forth my maximum effort to succeed in class.

These findings, in general, support studies such as that conducted by Shaffer (1973) which state that students' study habits, study attitudes, and academic work habits are positively related to successful college achievement. These results also support to an extent those of Terenzini and Pascarella (1978) in a study conducted on the relationship of precollege characteristics to attrition. They concluded that what happens to students after matriculation may be more important to success in college than attributes the student brings with him. The findings in the present study also revealed however, that although this construct was found to have the most significant influence on attrition, little of this behavior was explained by students' precollege characteristics, such as family background, the high school attended, or entry ability. Recall that for this construct, the psi coefficient, which reflects the proportion of unexplained variance, centered around .82.

Many of the proposed models on student attrition stressed the importance of precollege characteristics in the attrition process (Rootman, 1972; Spady, 1971; Tinto, 1975). These models also indicated, however, that the attrition of students is highly dependent on the adequacy of their fit or integration into the academic system of the university, and part of this integration was reported as the students' commitment to meet the academic demands of the university structure. The on-campus academic behavior as measured in this study by indicators such as "I attended class regularly," would appear to reflect, in part, the students' commitment to meeting the university's academic demands for success.

The importance of on-campus academic behavior on attrition supports recent trends in higher education to focus retention efforts on

factors which affect student behavior after admission (Bean and Noel, 1980). Many of these efforts are the direct result of more open admission policies, coupled with declining student enrollment (Tinto, 1981). This has caused many colleges and universities to move from a dependence on selective admission as their primary vehicle for assuring certain levels of student retention, towards policies designed to enhance student retention after admission. The former placed emphasis on entering student characteristics, particularly entry ability, whereas the latter attempts to structure the university to meet students' needs and facilitate their successful academic and social integration. In a recent study conducted by Beal and Noel (1980) on what works in student retention, it was reported that for the high risk student, early warning and follow-up are factors affecting retention. Included in this area were: (1) special attention from advisors/faculty; (2) mid-term probation notices; (3) invitations for special interviews; and (4) absence reports and follow-up. In their study they defined the high risk student as being disadvantaged (including minorities with need), and having low high school grades, low academic skills, and low college aptitude scores. These are characteristics of many of the students employed in this study, which suggest that early warning and follow-up strategies (e.g., probation notices, special interviews, and absence reports), may have a positive effect on the retention of students with backgrounds similar to the U-CEP student.

The findings in this study also suggest that studies on attrition which fail to consider the numerous factors that may relate to student attrition are presenting an oversimplified picture of a very complex process. In spite of the use of a causal modeling technique and

the use of several indicators, the model proposed in this study accounted for only forty percent of the variance in attrition. Statistically, greater significant results may have been obtained through: (1) the inclusion of other variables which may affect attrition, such as motivitional, personality or environmental factors; and (2) the use of different or additional indicators for the constructs proposed in this model. In a recent presentation by Tinto (1981), it was stated that models will never account for all variation in student attrition behaviors. However, it was also suggested that many areas relating to attrition have not been adequately explored. A particular need was indicated for more group specific research such as that presented in this study.

For the students used in this study, the results, indicated that family background has no direct relationship to characteristics of students' high school attended, entry ability, on-campus academic behavior or attrition. The high school attended by the students has no direct relationship to their on-campus academic behavior and little relationship to attrition. High school attended did have a significant relationship, however, with entry ability. Entry ability was found to have no direct relationship to students' on-campus academic behavior but a significant relationship to their attrition. The construct most highly related to attrition for students in this study was on-campus academic behavior. The important indicators of on-campus behavior were the adequate and timely completion of homework, regular class attendance, asking questions in class, careful and complete studying for tests, and putting forth maximum effort for class success.

These findings, however, were based on a select group of students. They were specially admitted students, classified on the basis

of low high school achievement and low assessed college aptitude. In addition, the majority of them fell into the lower end of a socioeconomic range and often had inadequate precollege preparation. These findings might not be relevant to all black students in an integrated university and this should be investigated. Beal and Noel (1980) defined being a minority as only one possible indicator of a high risk student. Whether the findings in this study are relevant for non-black students with many of the same entering characteristics should also be investigated.

The results of the study suggest that substantial efforts should be made to assess factors affecting student behavior after matriculation, in other words, what factors influence what types of students in attending class, completing homework, etc.? Future studies on black students should address these issues, particularly since increasing importance in higher education is now being placed on retention after access. It would also be useful to do further research on the effect of special intervention programs, such as U-CEP, on student academic behaviors and retention.

APPENDIX A

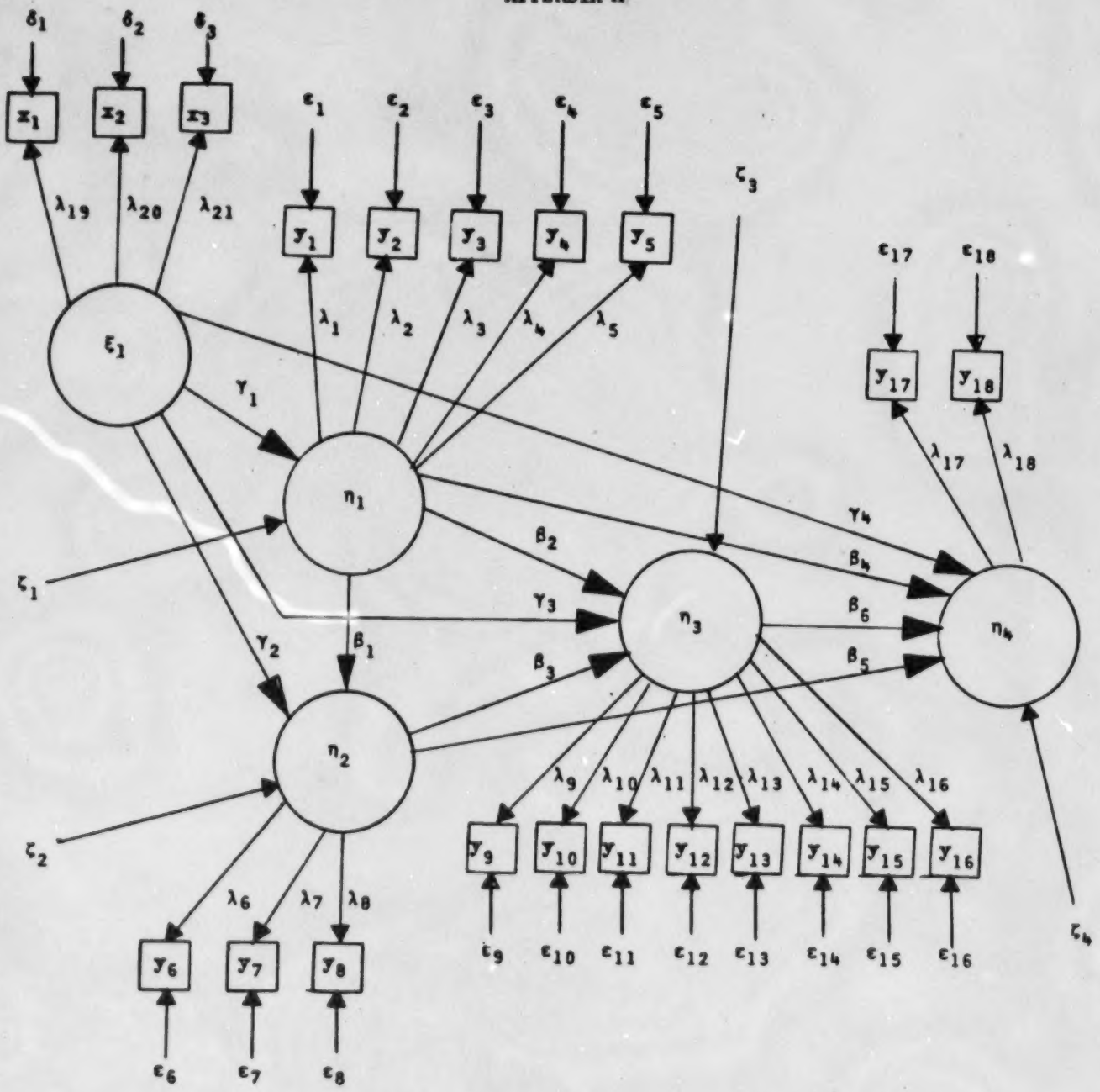

Figure 6

Parameters of Proposed Causal Model of
Black Student Attrition

APPENDIX B

MATRIX EQUATIONS FOR MODEL 1

Structural Model:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ -\beta_1 & 1 & 0 & 0 \\ -\beta_2 & -\beta_3 & 1 & 0 \\ -\beta_4 & -\beta_5 & -\beta_6 & 1 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \end{bmatrix} = \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \end{bmatrix} \xi_1 + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \\ \zeta_4 \end{bmatrix}$$

Φ=diagonal
Ψ=diagonal

Measurement Model:

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} \lambda_{19} \\ \lambda_{20} \\ \lambda_{21} \end{bmatrix} \xi_1 + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \\ y_8 \\ y_9 \\ y_{10} \\ y_{11} \\ y_{12} \\ y_{13} \\ y_{14} \\ y_{15} \\ y_{16} \\ y_{17} \\ y_{18} \end{bmatrix} = \begin{bmatrix} \lambda_1 & 0 & 0 & 0 \\ \lambda_2 & 0 & 0 & 0 \\ \lambda_3 & 0 & 0 & 0 \\ \lambda_4 & 0 & 0 & 0 \\ \lambda_5 & 0 & 0 & 0 \\ 0 & \lambda_6 & 0 & 0 \\ 0 & \lambda_7 & 0 & 0 \\ 0 & \lambda_8 & 0 & 0 \\ 0 & 0 & \lambda_9 & 0 \\ 0 & 0 & \lambda_{10} & 0 \\ 0 & 0 & \lambda_{11} & 0 \\ 0 & 0 & \lambda_{12} & 0 \\ 0 & 0 & \lambda_{13} & 0 \\ 0 & 0 & \lambda_{14} & 0 \\ 0 & 0 & \lambda_{15} & 0 \\ 0 & 0 & \lambda_{16} & 0 \\ 0 & 0 & 0 & \lambda_{17} \\ 0 & 0 & 0 & \lambda_{18} \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \\ \varepsilon_7 \\ \varepsilon_8 \\ \varepsilon_9 \\ \varepsilon_{10} \\ \varepsilon_{11} \\ \varepsilon_{12} \\ \varepsilon_{13} \\ \varepsilon_{14} \\ \varepsilon_{15} \\ \varepsilon_{16} \\ \varepsilon_{17} \\ \varepsilon_{18} \end{bmatrix}$$

Appendix C

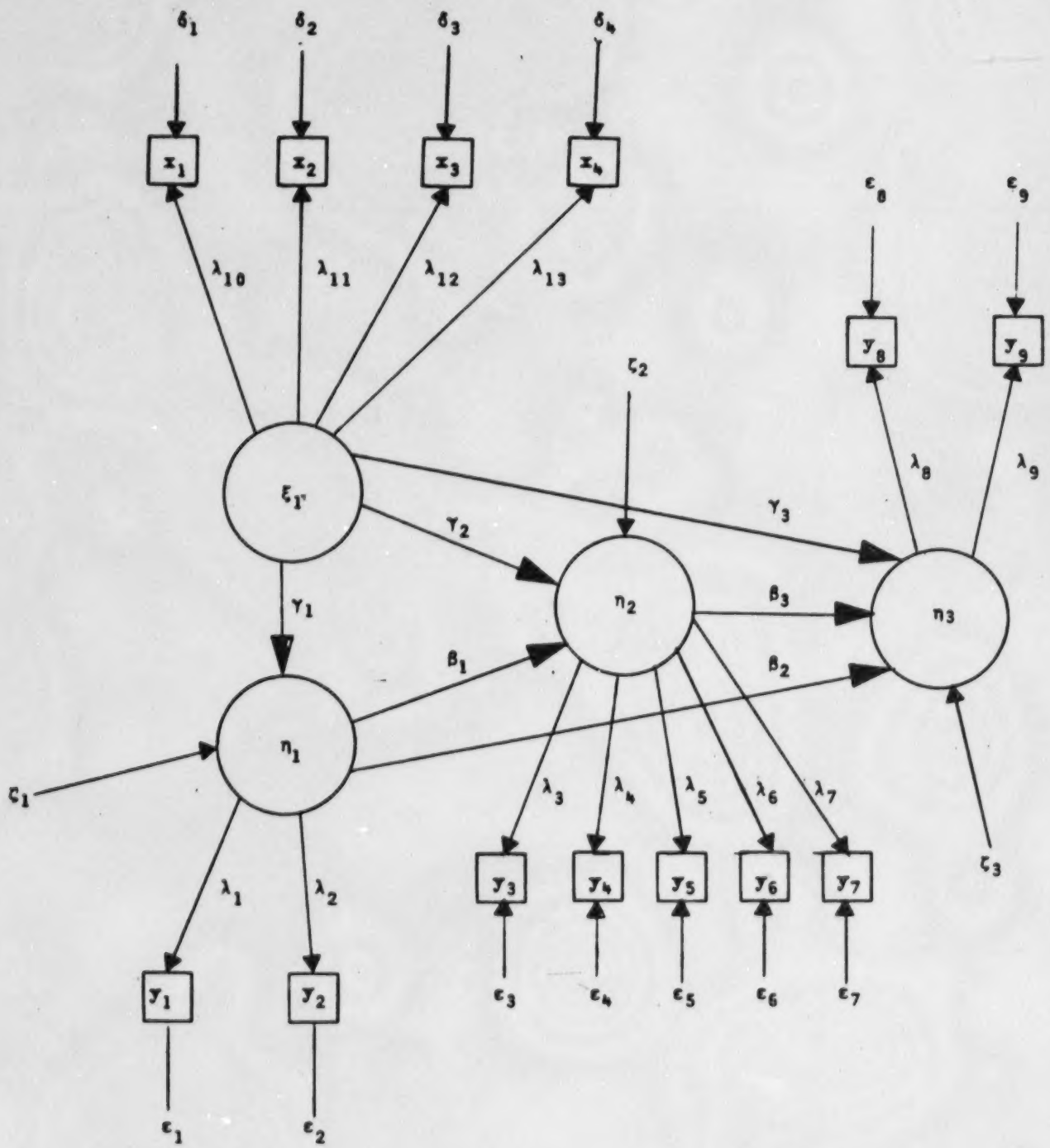

Figure 7

Parameters of Proposed Model 4

APPENDIX D

MATRIX EQUATIONS FOR MODEL 4

Structural Model:

$$\begin{bmatrix} 1 & 0 & 0 \\ -\beta_1 & 1 & 0 \\ -\beta_2 & -\beta_3 & 1 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \end{bmatrix} = \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \end{bmatrix} \xi_1 + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \end{bmatrix}$$

Measurement Model:

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} \lambda_{10} \\ \lambda_{11} \\ \lambda_{12} \\ \lambda_{13} \end{bmatrix} \xi_1 + \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \\ y_8 \\ y_9 \end{bmatrix} = \begin{bmatrix} \lambda_1 & 0 & 0 \\ \lambda_2 & 0 & 0 \\ 0 & \lambda_3 & 0 \\ 0 & \lambda_4 & 0 \\ 0 & \lambda_5 & 0 \\ 0 & \lambda_6 & 0 \\ 0 & \lambda_7 & 0 \\ 0 & 0 & \lambda_8 \\ 0 & 0 & \lambda_9 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \\ \varepsilon_7 \\ \varepsilon_8 \\ \varepsilon_9 \end{bmatrix}$$

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